International Journal of Modern Physics A

Search for Compositeness in Dilepton Final States at DØ

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We report preliminary results of a search for substructure in quarks and leptons assuming a four-fermion contact interaction for dielectron pairs of large invariant mass. The search is based on dielectron data collected by the DØ detector in $p\overline{p}$ collisions at $\sqrt{s}$=1.96 TeV. The results agree well with predictions of the standard model and we obtain model-dependent lower limits at 95% confidence level on the compositeness scale of 3.6 to 9.1 TeV for different chiral models of the composite structure of quarks and electrons.

Keywords: contact interaction; compositeness.

1. Introduction

The proliferation of quarks and leptons has inspired speculations that they might be composite objects and bound states of more fundamental constituents. Models based on composite fermions and their constituents have been suggested that involve theories of nearly exact chiral symmetry based on the near-masslessness of fermions at higher energy scales [1]. Composite models have also been examined in the context of mass hierarchy of fermions and the number of generations. Below the characteristic energy scale that is called the compositeness scale Λ , the constituents ("preons") form composite bound states such as quarks and leptons. This binding interaction (sometimes termed metacolor) can be modeled as a four-fermion contact interaction represented by a Lagrangian ($\mathcal{L}$) well below energies corresponding to Λ [2]

$$\begin{aligned}\mathcal{L} = \frac{4\pi}{\Lambda^2}[&\eta_{LL}(\overline{q_L}\gamma^\mu q_L)(\overline{e_L}\gamma_\mu e_L) + \eta_{LR}(\overline{q_L}\gamma^\mu q_L)(\overline{e_R}\gamma_\mu e_R) \\ &+\eta_{RL}(\overline{q_R}\gamma^\mu q_R)(\overline{e_L}\gamma_\mu e_L) + \eta_{RR}(\overline{q_R}\gamma^\mu q_R)(\overline{e_R}\gamma_\mu e_R)]\end{aligned} \tag{1}$$

where q=(u,d) represents the first-generation quarks, e represents (e, ν) , η is a sign factor that is - for constructive and + for destructive interference, L(R) denotes left (right) helicity of quark or lepton currents. The presence of such contact interaction would produce significant deviations in the e^+e^- production relative to theory at large invariant mass. Thus a precision measurement of the Drell-Yan cross section (using NNLO K factor 1.37 with systematic uncertainty of 10%) can provide signature for this kind of interaction and the presence of new physics at the TeV scale.

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In the absence of a deviation from the standard model (SM), the observed e^+e^- cross section can be used to set a lower limit for the scale of compositeness.

In Run I, DØ reported a limit on compositeness of 3.3 TeV to 6.1 TeV that depended on the type of chiral model used in the analysis [3]. In fact, the most stringent limits on Λ are from atomic parity violation experiments, and some phenomenological analysis has even suggested a possible contact interaction scale ~11 TeV to accomodate certain anomalous results [4].

2. Data Analysis- Event Selection, Efficiency and Background

. This analysis is based on $\overline{p}p$ data collected by DØ detector from Sept. 2002 to March 2004 during Tevatron Run II $p\overline{p}$ collisions at $\sqrt{s}$=1.96 TeV. The total integrated luminosity for this dataset is 271±17 pb^{-1}. The DØ detector is comprised of central-tracking system located within a 2 T superconducting solenoidal magnet, a liquid-argon uranium calorimeter and a muon spectrometer. Events must pass a set of high p_T electron triggers designed to accept electrons with large transverse momenta (p_T). Events are required to have two electromagnetic (EM) objects in the calorimeter with $p_T > 25$ GeV/c. In central region of calorimeter (CC), electrons must have $|\eta_{det}| < 1.1$ and in the forward regions or end calorimeters (EC), we select electrons with $1.5 \leq |\eta_{det}| < 2.4$. We define "loose" electrons by the fraction of EM energy deposited in the EM layer of a calorimeter,by degree of isolation, and the shape of the electron shower in calorimeter. The more reliable "tight" electrons, in addition, require a matching track extrapolated from the central tracker. In the final data sample, we require at least one tight electron. Total detection efficiency can be factorized in terms of a trigger efficiency, an electron identification efficiency and a track-matching efficiency multiplied by the acceptance efficiency of the detector. Uncertainties on efficiency are dominated by systematics (4% in total) in addition to 5% systematic uncertainty for any dependence on η.

The background is due mainly to jets misidentified as electrons, two chief sources being multijet(dijet) and γ+jet events, where both jets, or a photon and a jet,respectively, pass electron identification. The background from multijets is determined from the same diEM sample as used for signal for two EM objects. We require each EM object to have $p_T > 25GeV/c$ and appropriate η. But now we reverse the shower-shape cut requirements for electrons, and require poor electron identification.

3. Conclusions and Limits on Scale of Compositeness

We have obtained a mass distribution for dielectron data (Table I) that agrees well with predictions of the standard model (Fig.1). No evidence of new physics has been observed. Using a Bayesian approach, as in Run I [3], limits are set for each of the parity violating terms LL, RR, RL, LR and parity conserving terms or other symmetric combinations of these terms (Table II), such as LL+RR, LR+RL, LL-

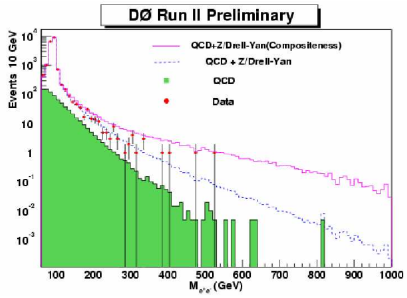

Fig. 1. Dielectron invariant mass distributions for QCD background (solid histogram), the standard model and a model with Λ = 3 TeV and left-handed quark and lepton helicities (open histograms), and the data (points with error bars.)

LR, RL-RL, vector-vector (VV= LL+RR+RL+LR) and axial vector -axial vector (AA = LL+RR-RL-LR) in the contact interaction $\mathcal{L}$.

Mass (GeV)	Observed events	Expected (QCD)	Expected (QCD+DY)
120-160	343	154.25±24.1	350.38±28.5
160-200	99	43.3±8.43	107±9.4
200-240	36	14.0±2.7	40.8±3.3
240-290	15	5.67±1.1	20.1±1.5
290-340	10	1.7±0.3	8.3±0.8
340-400	1	0.76±0.15	4.3±0.31
400-500	2	0.101±0.02	2.2±0.17
500-600	1	0.04±0.01	0.69±0.05
600-1000	0	0.02±0.01	0.31±0.02

Table I. Invariant mass distribution for dielectron data

Model	LL	RL	LR	RR	LL+RR	LR+RL	LL-LR	RL-RR	VV	AA
$\Lambda-$(TeV)	6.2	5.0	4.8	5.8	7.9	6.0	6.4	4.7	9.1	7.8
$\Lambda+$(TeV)	3.6	4.3	4.5	3.8	4.1	5.0	4.8	6.8	4.9	5.7

Table II. Limits for different chiral models

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